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The evolution of science, technology and innovation policies: A review of the Ghanaian experience

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ABSTRACT

Although there have been considerable past accomplishments in science, technology and innovation policy literature, our understanding of the evolution of government policies in these areas as a country transitions from one political regime to another, remains limited. This paper examines the issue within the context of Ghana, an emerging economy in sub-Saharan Africa, from 1957 to 2012. After a historical review of such government policies, we uncovered three key stages in the evolution of science and technology policy. These include the adoption of the “science for development” strategy and convergence of science and industrial policy from 1957–1966. This was then followed by the divergence of science policy and industrial policy from 1967 to the 1990s following the overthrow of Nkrumah’s government. The emergence of the “new dawn” from the 2000s onwards ushered in a new policy framework for national science and technology policy geared towards economic development. The study outlines a range of public policy implications.

Keywords: Ghana; national science; public policy; technology policy; innovation policy.

Introduction

Over the course of the last and this century, many countries have made the transition from one political regime to another and, in many instances, on multiple occasions (World Bank, 2011, 2013). These environmental upheavals are often accompanied by multiple shifts in governments' science, technology and innovation (STI) policy. Although there has been growing interest in science and technology policy in developing countries (Padilla-Pérez & Gaudin, 2014), our understanding of how such government policy evolves as a country transitions from one political regime (e.g. democracy) to another (e.g. totalitarianism) and vice versa, remains limited.

Although some scholars have long recognised that not all shifts in government policies in these areas yield positive outcomes (Rothwell, 1992; Rath, 1990), there is a dearth of research on how the effects of science and technology policies unfold (see Martin, 2012; Morlacchi & Martin, 2009). Against this backdrop, the main purpose of this paper is to examine the evolution and effects of the government's STI policy in the face of changes in political regime. The study focuses on Ghana as an exemplary setting and examines the evolution of STI policy from 1957, when the country gained independence, to 2012.

Since the second half of the 20th century, the country has made multiple transitions from democracy to military rule with varying impacts on wider industrial policy. Since it emerged from its colonial past in the 1950s, the country has formulated and pursued policies that connect technology, science and innovation as foundations for economic development (Hilson & Potter, 2005). Therefore, Ghana offers a fertile environment to examine this issue. Such context-specific analysis has been found to provide robust and rich insights of the issue (Edquist & Hommen, 2008).

The paper makes two important contributions to technology foresight, industrial and research policy literature. First, although science and technology policy has been examined in past studies (Borrás & Edquist, 2014; Rothwell & Dodgson, 1992), the effects of changes in governments on such policies in the developing world have received limited scholarly attention. The study helps to fill this gap in the literature by developing a sequential framework which charts the evolution of national STI policy. The framework also helps to explain patterns in government policies and their underlying logics. Second, although technology and science drive economic development and growth in emerging economies (Dodgson, 2009), it remains unclear how governments reignite and reinvigorate technology and industrial policies. The study provides insights of the historical factors that drive a fundamental shift to reignite and reinvigorate such policies.

The rest of the paper proceeds as follows. First, a review of the literature on science, technology and innovation policies is presented. This is then followed by examination of the historical backdrop to the STI policy in Ghana. The penultimate section provides a detailed overview of the evolution of STI policy in the country. The final section outlines the implications for public policy formulation.

Government policies and technology foresight: an integrative review

Scholars have long recognised that an effective STI policy occurs in tandem with collaboration of key stakeholders such as government, research institutions, industry and firms (Rothwell & Dodgson, 1992; Lemola, 2003). Such collaborations are required not only in formulating policies but also in ensuring implementation (Morlacchi & Martin, 2009). Broadly speaking, science policy entails investments in research and development activities, and development of human capital through education and training (Dodgson, 2000a). On the other hand, technology policy encompasses developing technological infrastructure to

support the development and utilisation of existing and new technologies, whereas, innovation policy focuses on actions by public organisations to help develop capabilities and capacity of firms to innovate (Dodgson, 2009; Edquist, 1997).

Past studies have suggested that enhancing local firms' capacity requires resources, training and development as well as effective policies that remove business and innovation obstacles (Aghion et al., 2009; Borrás & Edquist, 2014; Morlacchi & Martin, 2009; UNCTAD, 2011b). National STI policy is an integration of these three dimensions towards fostering economic development and national competitiveness. It may evolve over time to reflect the needs of the country or changes in the political environment (Vitta, 1990; Rath, 1990).

There is mounting evidence that indicates that STI policy entails developing and shaping the “rules of the game” (North, 1990) to create conditions for innovation and technological development to flourish (Beerepoot & Beerepoot, 2007; Edquist, 1997). A growing stream of scholarly works indicates that the development of a national innovation system partly depends on quality of formal institutions such as law, regulations and government policies (Dodgson, 2009; Nelson, 1993). Lack of effective regulatory framework or clear government policies can stifle the innovativeness and development of domestic firms (Beerepoot & Beerepoot, 2007; Rothwell, 1992). Past studies indicate that central institutions such as national councils and agencies can help to coordinate national research and development activities as well as promote the development of science and technology (Vitta, 1990). Such supporting institutions and organisations are essential in equipping firms to perform at the technological forefront to develop and sustain competitive edge (Dodgson, 2009).

A stream of research has attributed the greater success of some emerging economies and newly industrialising nations in the Asia Pacific region to their ability to formulate effective science, innovation and technology policies, (Aghion, David & Foray, 2009; Dodgson,

2000a, 2000b; Vitta, 1990). These have helped to foster innovation. National policies of such countries are geared towards enhancing the capacity and capabilities of local firms to innovate and compete effectively in the global environment (Dodgson, 2009; Edquist, 1997).

Several authors have pointed out that indigenous firms' ability to take advantage of the policy environment to continually innovate can become a pivotal source of competitive advantage for the nation (Dodgson, 2009; Dodgson, Gann & Salter, 2008a). This can be seen as a kind of technology foresight defined as the "process for linking science and technology more effectively to wealth creation and improvements in the quality of life" (Martin & Johnston, 1999, p. 655). It has the potential to provide countries with the route to formulate policies and strategies to develop capacities and leap to the next stage in their economic development (UNIDO, 2015). It also entails long-range, forward-looking activities by governments to help foster technology utilisation and consequently economic development (Chen, Wakeland & Yu, 2012). It is the concurrent attempt to explore the relationships between technology and science as well as harnessing technology to foster development and wellbeing of the wider population.

Technology foresight has also been identified as playing a pivotal role in wiring up the national innovation system to foster learning, efficient utilisation of resources as well as meeting future challenges (Martin & Johnston, 1999). The technology foresight process is a mechanism through which future requirements, scenarios and priorities are defined in collaboration with stakeholders (Barker & Smith, 1995). Therefore, effective STI policy formulation and implementation requires involvement of interested parties and changes in a party's circumstances is more likely to alter their level of resources, involvement and commitment (Edquist, 1997). Indeed, changes in government would not only affect the level of resources and commitments, but also lead to the re-prioritisation of policies with the wider

economy. Changes in government can disrupt previous government policies and even destroy the foundations laid by the previous regime (see Ayensu, 1978).

Insert Figure 1 about here

Based on the above overview, technology foresight can be achieved through effective linkage of national STI policy, as illustrated in Figure 1. The figure demonstrates a unified approach for government policy to help foster the development of local innovation and national competitiveness. Although governments have historically sought to improve the conditions for research and innovation activities to flourish, at times the government can also become a barrier to development in these areas. In this study, we seek to illuminate our understanding of this issue by examining the evolution of STI in Ghana.

Historical background: science, technology and innovation policy in Ghana

In the middle of the last century, Ghana emerged from colonial rule and experienced various degrees of economic and political upheaval. Since the end of British rule in 1957, the country has adopted various technology and science policies geared towards making it a leader in these fields. The role of science and technology as panaceas in Ghana's economic underdevelopment can be traced to its founding fathers including Kwame Nkrumah, who set out a coherent policy of using universities and tertiary institutions as engines for economic development. The formulation of science and technology policies started with greater intensity immediately after independence to help foster indigenous innovation and development.

In 1957, Ghana's manufacturing share accounted for 7.4% of GDP and was on the verge of modern industrialisation (Darkoh, 1973). By the early 1960s, Ghana was at the cutting edge of modern technology education, however, its place in the world faltered after this period.

However, from 1973 to 1983, the industrial sector shrunk at an average rate of 3.5% per annum (Adei, 1990). By the late 1970s, manufacturing was on the verge of collapse with devastating effects on industrial development. One possible explanation was that over the years, the government adopted a politician-led strategy which had little link to industry or educational institutions. Over the years, illiteracy and limited access to information communication technology have become major obstacles to economic and political development (Opoku, 2004).

In the last two decades, Ghana has emerged as one of the most stable democracies in Africa with a fast-growing economy and a Gross Domestic Product (GDP) growth of 16.30% in 2011 (Boso, Story & Cadogan, 2013). In 2010, the country was declared a lower middle-income country, which was a testament to its economic and financial reforms, political stability and limited ability to utilise its natural resources for development (African Business, 2015). One possible explanation for this is the increasing liberalisation and dismantling of loss-making state-owned organisations. Over the years, the establishment of fast-track courts with the aim of enhancing the speed and ensuring the efficient resolution of commercial disputes has helped to provide assurance and confidence in the legal system (African Business, 2015). These efforts have helped to attract foreign investors. In the first decade of this century, there was a major change in government which precipitated a shift in government policies towards the promotion of science education and local innovations.

For Ghana, these changes were long overdue given the overdependence on the public services as a main source of employment (Debrah, 2007). Major attempts were made to utilise private sector expertise, local universities, industry and local communities towards developing conditions for innovative solutions to local problems. It was believed that the development of

information and technology could provide the platform to bridge the digital divide between Ghana and many advanced economies (Amankwah-Amoah, 2015).

From the beginning of the 2000s, the importance of technology and science as engines for economic development became more prominent among policymakers once again. Technology outsourcing hotspots emerged around the world creating opportunities for African countries to attract a piece of the action in areas such as call centres and processing firms (Hale, 2003). More recently, Ghana has emerged alongside African countries such as Senegal and Togo to compete to become a low-cost, hi-tech hub in Africa to become Africa's "Bangalore" (Hale, 2003). Ghana has come to be seen as or is proving to be one of the popular destinations for the anglophone countries.

The evolution of STI policy

A review of the evolution of the country's national STI policy identified three unique patterns. The first is the Nkrumah period, 1957–1966 and immediate post-Nkrumah period from 1967 to the 1990s, and the "new dawn" from 2000 onwards. A striking pattern in government policy during the first stage was the exclusive focus on government-backed projects. Below, we tease out the evolution of government policies over the period. First, we examine the Nkrumah era.

The Nkrumah era: technology and science road-mapping phase

The foundation of national STI policy can be traced to the Dr Kwame Nkrumah era. During that period, Ghana adopted a comprehensive policy framework which entailed skills formation, technology and knowledge transfer from foreign to indigenous firms, and capacity building of universities and training schemes to prepare the country for future challenges. When Ghana became independent in 1957, one of the cornerstones for future development

and progress was to harness value entrenched in science and technology education (MEST, 2010).

At the dawn of independence, Nkrumah concluded that most of the challenges facing the nation could be overcome through the development of science and technology (Ayensu, 1978). He also believed that science and technology would also help to propel the newly independent country and the whole of Africa into a modern and industrialised status (Brown-Acquaye, 2004). Accordingly, Nkrumah adopted the concept of “science for development” as a key pillar to his strategy of rapid industrialisation (Brown-Acquaye, 2004). The key tenet of his vision for science was clear in his speech to the old legislative assembly on the 5th of March 1957. He noted:

“Our whole educational system must be geared to producing a scientifically-technically minded people. Because of the limitations placed on us, we have to produce, of necessity, a higher standard of technical education than is necessary in many of the most advanced countries of the Western world ... I believe that one of the most important services which Ghana can perform for Africa is to devise a system of education based at its university level on concrete studies of the problems of the tropical world. The University will be the coordinating body for education research, and we hope that it will eventually be associated with Research Institutes dealing with agriculture, biology, and the physical and chemical sciences which we hope to establish...” (McWilliam & Kwamena-Poh, 1975, p. 94)

When the country eventually became a republic in 1960, there was a further rallying cry of industrialisation rooted in science and technology (Simons, 2014). For years, Nkrumah sought to promote science education and educated many Ghanaians to become more scientifically and technologically advanced than during the colonial period (Asabere-Ameyaw, Dei & Raheem, 2012).

Another pillar was the belief that by developing knowledge and expertise in areas such as engineering, medicine, tropical agriculture and hygiene, the country would be equipped to

address the pressing social issues at the time and raise the standards of living. It was these noble missions that prompted Nkrumah's government to establish the University of Science and Technology (now renamed Kwame Nkrumah University of Science and Technology (KNUST) for scientific human capital development. In 1962, the University College of Science Education (now called University of Cape Coast) was also established to train science and mathematics teachers for secondary schools across the country (Ahia & Fredua-Kwarteng, 2012). These were immediately followed by the establishment of the Ghana Atomic Energy Commission near the premier university, University of Ghana, to support academic and research institutions (Brown-Acquaye, 2004).

Furthermore, Nkrumah's wider efforts to promote the development of science and technology also led to the passing of the Research Act 21 of 1958, which led to the formation of the National Research Council (now revamped and re-configured into the Council for Scientific and Industrial Research (CSIR) (CSIR, 2015). Such was the importance of the council it was chaired by the President Nkrumah. The primary role of the council was to organise and co-ordinate scientific research geared towards policy formulation and delivering fast industrialisation of the country. Indeed, the Seven-Year Development Plan of 1963/64 to 1969/70 also had science and technology as its key component. As one commentator puts it:

"The first president of Ghana, a great visionary and a genius was at the forefront in the crusade of industrialisation ... His vision led to the establishment of one of the finest science and technology institutions in the country. Graduates from this and other institutions were offered scholarships to developed countries to acquire knowledge and the necessary skills required to push the industrial revolution through." (Egu, 2009, p. nd)

In 1963, the functions of the National Research Council and the Ghana Academy of Learning (founded in 1959) were amalgamated into a single entity and renamed as the Ghana Academy

of Sciences (CSIR, 2015). The then new academy coordinated and organised national research activities.

Another distinctive feature during this period was the convergence of science policy and industrial policy. Dr Nkrumah also made major improvements in science policy by providing direction and support for university research and facilities for basic research to occur. The visionary leadership triggered a range of investment into science projects geared towards allowing indigenous development and innovation to flourish. The wider industrial policy also incorporated financial support for research and development, technical education and training through the local university. In many areas, he helped to forge close relationships between science policy and industrial policy with major projects such as the Akosombo Hydroelectric Project, which started in 1961 and was completed in 1965. The project offered opportunities to develop local expertise in areas such as science, engineering and construction. It also provided opportunities to develop new knowledge from other international experts to be diffused to the local economy. A vehicle tyre production facility was started to also help facilitate knowledge transfer from foreign firms to local firms.

However, during the late 1950s and early 1960s, government policies and subsidies were skewed towards promoting large government-led projects and large firms. This stifled attempts to encourage local entrepreneurship. The private sector, which was dominated by “foreigners” at independence, was viewed with a great deal of suspicion and as not being “indigenous” enough to warrant government support (Vuerings & Hanika, 1964). Indeed, government takeover and seizure of local firms and industries such as mining, cocoa, textiles, tourism and finance from entrepreneurs and nationals of the former colonial powers discouraged entrepreneurship and indigenous innovation.

One weakness was the limited transfer of skills and knowledge from foreign multinationals to locals. The departure of foreign nationals often meant that local organisations needed “trouble-shooters” from overseas to help stabilise firms or deal with complex issues (see Adei, 1990). Table 1 summarises the major milestones and key events over the period.

Insert Table 1 about here

The immediate post-Nkrumah era: divergence of science and industrial policies

During the early 1960s, the government recognised STI as an essential pillar in fostering economic development across the country. The immediate post-Nkrumah era which started in 1966 altered the path to the future and the roadmap articulated. The seeds for “destruction” and disruption of science and technology policy were sown, when Lt Gen Akwasi Afrifa was overthrown as leader on February 24, 1966 (The Economist, 2001). From the mid-1960s to the late 1970s, the country was besieged with the constant overthrowing of one military regime after another (see Table 2 for details).

One of the most distinctive features of the government effort during this era was diversion of resources and attention from the goals outlined by Nkrumah, to an environment where national resources were squandered on politically driven projects which added little to the development and progress of science and technology. Indeed, during General Acheampong’s regime as head of state (1972–1978), the lack of experience and vision put the country on the path of decline and corruption, which stifled entrepreneurship, innovation and scientific development. During the second half of the 1970s, much of the policy discussion was on how the government could gain wider influence over universities.

During this period, both military and civilian governments employed various mechanisms to “gain ideological and/or political control over the universities, but overall the ethos of ‘knowledge’ and the economic benefits of a degree gain them support from the general public; government control has been more formal than real” (Peil, 1996, p. 54). In 1977, General Acheampong lamented his frustrations in his limited ability to remove university professors from their posts. He noted that it was “much more difficult to remove university professors than a Chief Justice” (Peil, 1996, pp. 53–56).

The decades following the overthrow of Nkrumah led to a period of shrinkage of not only economic activities, but also basic research and government commitment. During the 1970s, the three main policy tracks – science policy, industrial policy and innovation policy – continued to diverge and expertise in these areas continued to decay and dwindle. The political instability disrupted the level of scientific research and collaboration between universities and policymakers.

Throughout this period of political instability and economic decline, many highly skilled individuals including scientists, academics and engineers left the country for greener pastures. The country lost many of the trained professionals to more stable countries across the world. The departure of the highly educated further depleted the scientific knowledge and expertise accumulated prior to this era. By the end of the 1970s, considerable resources had been wasted on elephant projects as the overthrow of government resulted in a shift of government priorities leading to reallocation of resources.

Lack of “explicit” policies

During the 1970s and then in the 1980s, the various political regimes declared their interest in harnessing value in science and technology. However, one major obstacle was a lack of explicit policies to guide government actions backed with resources and expertise to ensure

effective implementation (Vitta, 1990). In this direction, the United Nations' landmark Conference on Science and Technology for Development in August 1979 called on such countries to develop a national science and technology policy (United Nations, 1979). International organisations such as UNESCO also took steps to help African countries to formulate policy in this area. UNESCO's Conferences of Ministers of African Member States Responsible for the Application of Science and Technology for Development held in January 1974 in Dakar and then a second conference which was held in Arusha in June 1987 were major steps towards helping to address the deficiencies at the national level and lack of explicit policies (Vitta, 1990). The absence of explicit technology and science policy in much of the 1970s can be attributed to a number of factors. One was the lack vision and understanding of the nature of education and training required for Ghana to leap forward.

In addition, Nkrumah's policy doctrines and drive to develop educational systems and innovation capacity of the nation were largely dropped by the military regimes. During the 1970s, political survival of the military regimes became the top priority, thereby taking attention from effective development policies. The military leaders were more interested in staying power than advancing the foundation for science and technology that occurred. This meant that the era of enthusiasm for science and technology development with KNUST at the centre was all but over. From the early 1970s to the early 1980s, the country's economy and industrial development were in decline. The overthrow of Nkrumah was followed by the erosion of the gains made in industrialising the economy.

Over the intervening period, there was no effective STI policy to lay a roadmap for collaborations between universities, government and industries such as mining and cocoa. Consequently, innovation and research and development activities faltered to the detriment of the nation and industrial development. A minor step was taken to address the deficiencies in

the 1980s when the Ghana Education Service developed science resource centres in a number of schools with the aim of promoting science education (Egu, 2009). The capacity building of the schools included the development of science laboratories and access to modern facilities.

Early signs of policy revitalisation

At the beginning of the 1980s, the Ghanaian economy began to experience a sustained period of political and economic stability, thereby providing conditions for further development. The early 1980s saw a change in political regime with more emphasis on science and technology policy research. In 1987, the Technology Transfer Centre was founded as a branch of the CSIR to direct attention to the development of national science and technology policy (STEPRI, 2015). The Technology Transfer Centre was renamed the Policy Research and Strategic Planning Institute in 1992, and then reintegrated into the structure of the CSIR in 1994 and named the Science and Technology Policy Research Institute (STEPRI) (STEPRI, 2015). The establishment of the STEPRI was geared towards helping to formulate policies and taking “practical steps in creating innovation centres and business incubators for the agricultural and food processing sectors through the support of research institutions, universities and industries” (GNA, 2008, p. nd). Its contemporary role entails the “development, transfer, utilization and management of STI in accordance with the context-specific needs and priorities of Ghana and Africa” (STEPRI, 2015, p. nd). In the mid-1990s, the following observation was made about Ghanaian universities and academics:

“Many academic staff do not research. This is partly because they lack funds; departmental resources are very small, there are few other grants available unless one has international contacts, and the inability to keep a car on the road and lack of access to relevant books and periodicals are real enough constraints.” (Peil, 1996, p. 53)

During the latter part of the 1990s under Rawlings, there were attempts to develop research and national education of science and technology. In 1996, all public research institutes were

included under the umbrella of the CSIR. The CSIR coordinates research activities among research centres in the country with the aim of building capacity and fostering development. The Ghana Poverty Reduction Strategy Paper I, 1996–2005 also recognised the importance of science and technology as pillars in the country’s future. Although the government provides funding for this organisation, this only accounts for the payment of salaries and the cost of general services.

However, today, the organisation also generates around 30% of its annual budget from the private sector (CSIR, 2014). In 1998, the Institute of Industrial Research was established following the merger of the previous Industrial Research Institute and Scientific Instrumentation Centre (CSIR, 2014). Its mission is “to drive national development and global competitiveness in industry through scientific and technological research” (CSIR, 2014, p. nd). Even at this stage, the policy lacked any significant financial resources to fund and encourage large-scale research and development activities. Appendix 1 provides details of the number of contemporary public universities, tertiary institutions and research institutes engaged in research towards fostering innovation and better public policies.

The “new dawn” phase: re-prioritisation and policy convergence

At the dawn of the 21st century, the election of the opposition party provided an opportunity to meet some of the challenges from the previous phase. During the tenure of the New Patriotic Party spearheaded John Kufour (2001–2009), there was a sharp return to some of the scientific and industrial principles outlined by Nkrumah immediately after independence. In the early 2000s, a number of programmes were introduced in this area. In response to the continuing decline and stagnation of research activities across an array of areas, the government recognised that science and technology policies needed to be revived and

rejuvenated to serve as a cornerstone of addressing contemporary challenges facing the nation.

In 2000, the government launched the first National Science and Technology Policy (MEST, 2010). This was the first major national STI policy document with the aim of upgrading the expertise and capacities of the nation. At the core of the strategy was harnessing and utilising science and technology at all levels of society, including encouraging women in science and technology into general employment and solving economic and social challenges facing the nation (GNA, 2000). The strategy also helped to constrain the lack of an explicit and legally standing policy to guide government policy and encourage collaboration from industry and government (GNA, 2000). The government also reaffirmed its commitment to achieve middle-income status by 2020, under the Vision 2020 policy (GNA, 2000; UNCTAD, 2011a).

A major step towards achieving the Vision 2020 goals was to ensure that 60% of all students in the public universities and 80% in the vocational institutions studied science and science-related subjects (GNA, 2009). Up until this point, the country had not had any major “definitive and prescriptive National STI policy to define policy directions for various sectors of the economy and associated prioritized investments.” (MEST, 2010, p. 10)

One major factor that had handicapped research and development activities for decades was access to finance. In this direction, the policy also established mechanisms for finance and critical evaluation of science and technology activities. The policy allocated 2% of the country's GDP towards investment in science and technology, which was a shift from around 0.3–0.5 of GDP that was far below the prescription stemming from the Economic Community of West African States in 1980 under the Lagos Plan of Action (GNA, 2000). In addition, the government has also elicited the support and contributions of the private sector

towards the establishment of the Science, Research and Technology Fund (MEST, 2010). The fund is aimed at developing the capacity in areas such as engineering design and production technology to help foster a national innovation system.

In 2005, the National Development Planning Commission report asserted the desire of the nation to shift from the “the cocoa–gold–timber structure” (i.e. economics of reconstruction and rehabilitation) to the economics of industrialisation and accelerated growth utilising science and technology for development (NDPC, 2005). One of the major obstacles was the government decision in 2006 to dissolve the Ministry of Environment, Science and Technology (MEST). Although the science portfolio was absorbed by the Ministry of Education to become the Ministry of Education, Science and Sports, the undivided attention which was needed and resources required were affected (MEST, 2010).

The MEST was re-established in January 2009 by the government to help address the concern of the stakeholders about limited focus on key science and technology issues (MEST, 2010). The new ministry was empowered with the responsibility for the implementation of the country’s science and technology policy framework. One role of the ministry was to coordinate the activities and programmes of the CSIR and its 13 research institutes (MEST, 2010). Some of the objectives of the National STI Policy include developing quality of life through innovation, human capital development and skill formation in science, expanding industrialisation and promoting an information society (MEST, 2010).

In 2012, the National Science Policy was re-launched with the aim of fast-tracking the development and fostering the application of STI into the national development strategy (GNA, 2012). At the core of the new policy was the creation of conditions for STI to flourish and the positioning of the Ghana Academy of Arts and Sciences, Centre for Scientific and Industrial Research as the central pillar in public policy formulation (GNA, 2012). The

government also provided equipment (around 60,000 laptops) and financial support in the form of scholarships (around 5,000) to some students under its initiative, the Better Ghana Information, Communication Technology agenda strategy (GNA, 2012).

During this phase, a number of such steps were taken to help the country adopt the latest technologies. The conditions for the formation of the National Information Technology Commission were laid in 2004 to provide the roadmap towards making Ghana an information-, communication- and technology-driven nation (GNA, 2004). One of the roles of the Commission is to advise the government in the development and implementation of technology policies (GNA, 2004). Technological advancement in mobile phone and solar technologies has permeated society as the pace of development in other areas has appeared relatively painstaking.

Science and technology park

One of the key features of the government's industrial policy was forging effective collaboration between universities and industry. One major step in this direction was the establishment of the first major national science and technology park. The KNUST's College of Engineering in collaboration with Ibistek Ghana LTD laid the foundation for the establishment of the first national technology park (KNUST, 2014). The park is situated in Kumasi and was conceived as an incubator for local innovation and entrepreneurship. This development was seen as a major step in fostering further collaboration between local universities, government and industry. The involvement of a leading national university established in the first phase would help in keeping abreast with the latest research and innovations for the purpose of advancing research, fostering economic development and nurturing indigenous innovation.

Another benefit is that the park fosters collaborations and the exchange of ideas across an array of areas including food science and processing technologies, and leading-edge technologies such as nanotechnology, biotechnology and pharmacology (KNUST, 2014). One of the objectives was to create conditions to foster private–public partnership and industry–government–university partnership.

Policy constraints and future challenges

Despite the progress over the years, a number of challenges remain. One factor that affected the development of science and technology was the lack of skilled workers, poor education system and acquisition of strategic assets such as land by private investors for properties. Indeed, research “funding allocations are determined by the Government and often do not relate to the priorities of the providers of science and technology services (i.e. the research institutes and universities) and much less still to the end-users of technology and research, such as the private sector, farmers, and informal enterprises.” (UNCTAD, 2011a, p. 4)

More importantly, the system for allocating funds for research has not been subjected to the competitive pressure seen elsewhere in the developed world which drives relevant and novel research tailored to the needs of the nation. One of the examples can be found in the prevalence of use of primitive tools in areas such as agriculture, blacksmithing and construction (MEST, 2009). At another level, superstition also played a major role in seeking explanations for phenomenon and occurrences of events rather than scientific reason (MEST, 2010). In spite of this growing need for research funding at local universities, a recent study indicated that over 90% of university and research institute funding is used on salaries and operational costs, leaving little for genuine research (UNCTAD, 2011a).

Over the years, the university and training institutions have failed to produce enough graduates with superior capabilities and drive to start new businesses and spur innovation

(UNCTAD, 2011a). The failure to make appropriate investment in science and technology development has meant that the initial vision at the dawn of independence remains unfulfilled. Given the scarce national resources, there is a need to identify unique areas or activities where the limited resources could be efficiently deployed. There is also a need to ensure efficient allocation of the limited national resources.

Insert Table 2 about here

Table 2 summarises the key features of the three phases and major shifts from 1957–2012. A major shift from the Nkrumah era to the “New dawn” phase was from the overwhelming emphasis on large firms and government-backed firms to both large and small firms as key pillars for economic development. Although progress has been made, small firms continue to lag behind large firms in gaining government support.

Discussion and implications

The paper sought to illuminate our understanding of the evolution of STI policy as a country transitions from one political regime to another. A review of the Ghanaian experience led to the development of an integrated framework of factors to account for the rise and fall of governments’ commitment, support and investment in science and technology. The study identified three unique stages in the evolution of government policies. There was a major shift from the high point of science and technology policy in 1957–1966 to a fundamental decline in the 1970s–1990s and rejuvenation at the dawn of the 21st century precipitated by partly by change in government.

Our findings indicate that policies were largely influenced by the nature of political regime and vision of the leaders at the time. Indeed, these culminated in the adoption of the “science for development” approach and convergence of science policy and industrial policy from

1957–1966. Although the visionary leadership of Kwame Nkrumah and his passion for science and technology led to development, this waned following the overthrow of his government. A key feature was the divergence of science policy and industrial policy. The post-Nkrumah era was also characterised by a lack of clarity and direction for science and industrial policies. Government policies also suffered from lack of financial backing and human capital to ensure effective implementation. Military regimes during this period led to misallocation of research and diversion from major science and technology activities which were essential pillars for economic development.

One of the most prominent shifts from Nkrumah's era to the immediate post-Nkrumah phase was the move from “explicit” science and technology policies to “implicit” policies. Another distinctive feature was the shift from the exclusive focus on government-backed large firms in the first phase towards increasing focus on both small and large firms in the last stage of development. The “new dawn” for national science and technology policy provided a clear public policy framework with the aim of forging closer links between industry, universities and firms to facilitate innovation and economic development.

The final phase also articulated clarity of policy and direction of travel which can provide a basis for firms to make investment decisions. Taken together, our findings demonstrate that the fundamental shifts in government policies were largely driven by changes in government rather than fundamental re-evaluation of the policy. One possible explanation is that the political goals have often superseded the societal goals.

Contributions to public policy and directions for future research

Three main practical implications stem from our analysis. First of all, there is still more room for science and technology to make a greater contribution to the country's future development. In the Ghanaian setting, there is also a need for STI policy to become more

encompassing by shifting from mainly science and technology to including developing and enriching competencies in additional areas such as engineering and mathematics.

In addition, there is an inherent danger that the drive to promote science and technology research may divert resources towards indigenous projects that are merely “re-inventing the wheel”. Such investments are very likely to lead to misallocation of limited national resources and development of inferior or obsolete technologies, which will not enhance the competitiveness of the country. As such, there should be an effective alignment between government policy and resource allocation to help foster innovation.

Furthermore, there is a need to create a culture and environment that fosters technological leapfrogging. This means improving the capacity and capabilities of local firms to be able to adapt and utilise imported technologies to help design efficient and effective solutions for local problems. Technological advancements can provide opportunities for the nation to leapfrog certain stages of development and technologies to catch up with fast-developing emerging countries (Dodgson, 2009). The analysis also indicates that government support schemes, policies and firm-level capacity-building initiatives need to be closely welded together to create conditions for indigenous innovation to flourish. This requires collaboration between educational institutions and firms.

Follow-up research could proceed along the following lines. First, there is a need for studies of innovative firms in this context to help provide further insights on firm-level factors that help to neutralise the effects of uncertain institutional environments. Second, there is also a need to examine the long-term effects on innovation of the establishment of a science park in the country. We hope that this study serves as a facilitator for further research on technology and science policies in emerging economies.

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Figure 1. A sequential model of the evolution and development of STI policy

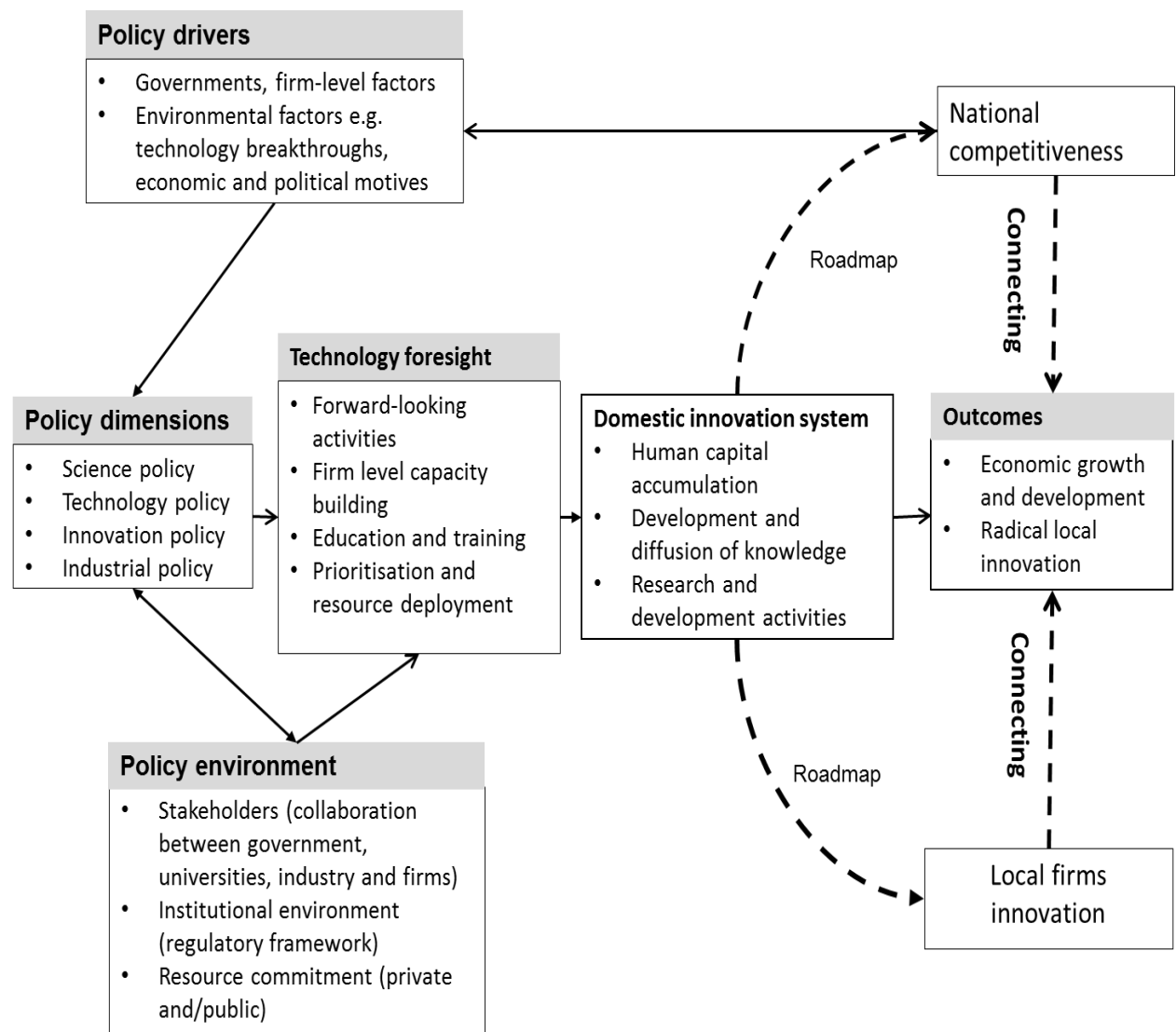
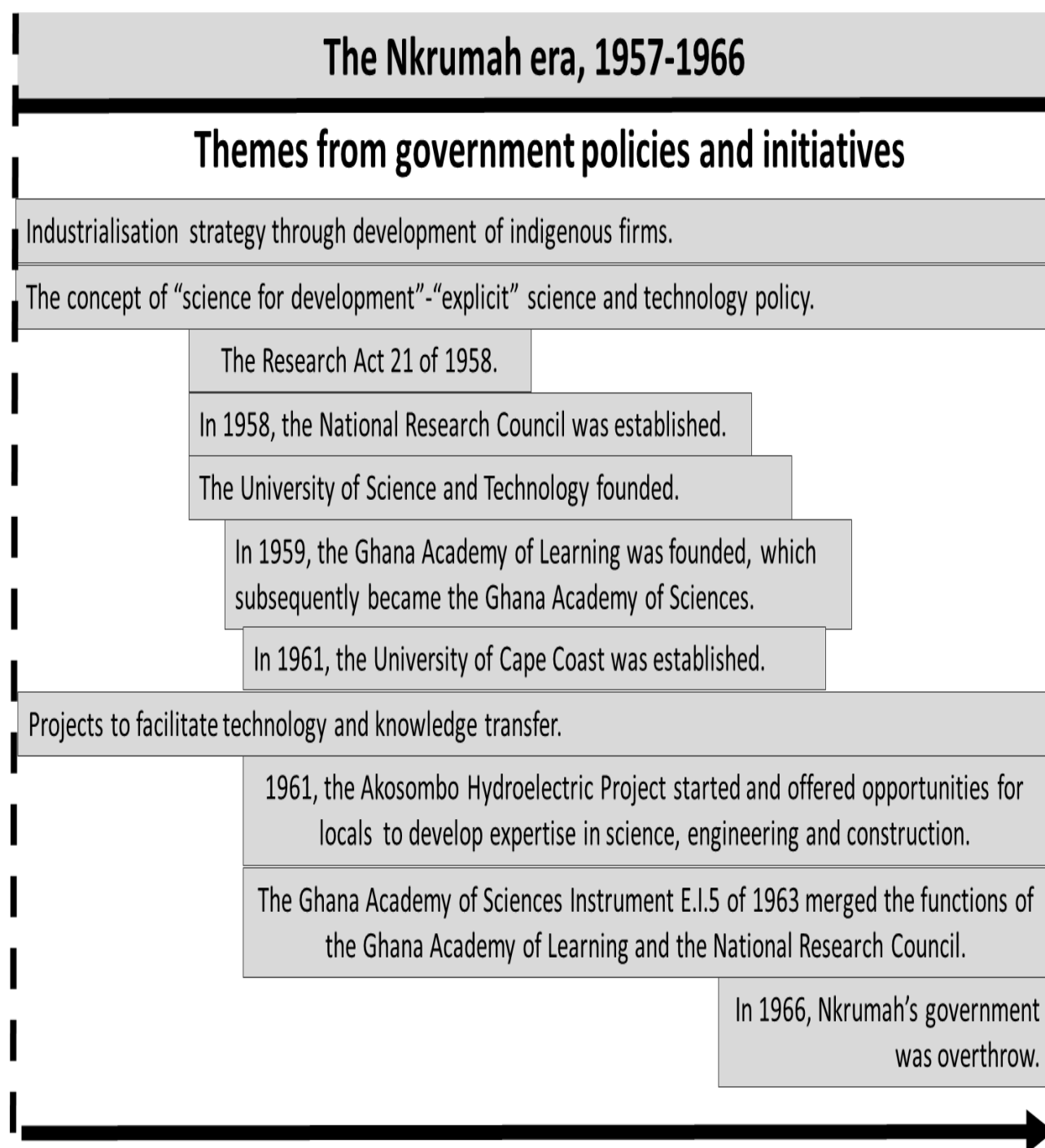


Table 1: Key events in the evolution of STI policy



Data sources: synthesised from: MEST, 2009, 2010, 2011; Egu, 2009; CSIR; 2015; Peil, 1996; Lall & Pietrobelli, 2005.

Table 2: Phases in the evolution of science, technology and innovation policy

Phases	Nkrumah period	Immediate post-Nkrumah era	New dawn for national science and technology policy
Years	1957–1966	1967–1979	2000–present
Heads of State/Presidents	Osagyefo Dr Kwame Nkrumah	Lt. Gen Akwasi Afrifa (1966–1969); Joseph A. Ankrah (1966–1969); Lt-Gen Emmanuel Kotoka (1966–1969); Kwasi Kotoka (1966–1969); Lt. General Dr Kofi Abrefa Busia (1969–1972); Edward Akufo-Addo (1970–1972); Ignatius Kutu Acheampong (1972–1978); Fredrick Akuffo (1978–1979); Flt.-Lt. (Rtd) J. J. Rawlings (1979); Dr Hilla Limann (1979–1981); Flt.-Lt. (Rtd) J. J. Rawlings (1981–2000).	John Agyekum Kufour (January 2001 –January 2009); John Atta Mills (2009–2012); John Dramani Mahama (24 July 2012–present).
Level of government intervention and dynamics	<ul style="list-style-type: none"> Centrally planned and implemented STI policy with collaboration from multiple stakeholders. 	<ul style="list-style-type: none"> Largely dictated to the regions until the 1990s. 	<ul style="list-style-type: none"> Policy stems from collaboration with multiple stakeholders.
Key features and events	<ul style="list-style-type: none"> Comprehensive programme to promote the development of 	<ul style="list-style-type: none"> Divergence of science policy and industrial policy. In 1994, the African Technology 	<ul style="list-style-type: none"> In 2000, the first major National Science and Technology Policy was launched as the foundation for sustainable economic

	<p>science and technology through universities.</p> <p>Introduction of the concept of “science for development”.</p> <ul style="list-style-type: none"> • Effective collaboration and coordination of science policy and industrial policy. 	<p>Policy Studies Network was established to replace Eastern and African Technology Policy Network and the West African Technology Studies Network to help forge close links between government policy, science and public policy formulation.</p> <ul style="list-style-type: none"> • Technological backwardness was apparent in government policy in the 1970s. 	<p>development. It highlighted the pivotal role of science, technology and innovation.</p> <ul style="list-style-type: none"> • Renewed focus on the development of indigenous capacity. • In 2004, the National Information Communication Technology for Accelerated Development Policy was advanced. • The establishment of Ghana’s first technology park. • Ghana’s Growth and Poverty Reduction Strategy (GPRS II, 2006–2009) reaffirmed the national commitment to science and technology.
Feature of government policy	<ul style="list-style-type: none"> • Development of teachers for the next generation of Ghanaians. • Development of science and 	<ul style="list-style-type: none"> • From late 1960s–1970s, the dismantling of major STI initiatives during the Nkrumah period. • Declining quality of facilities at educational institutions. • Major promotion of “made-in-Ghana” 	<ul style="list-style-type: none"> • Greater public–private partnership in funding programmes to mobilise Ghanaian researchers in the diaspora. • Greater public–private partnership in funding-created incentives and conditions to foster public–private

	<p>technology infrastructures.</p> <p>Funding for the establishment of local universities.</p> <ul style="list-style-type: none"> • Government funding to promote local innovation and for research and development activities. 	<p>products in late 1990s.</p>	<p>collaboration.</p> <ul style="list-style-type: none"> • Improved access to venture capital funding.
Constraints	<ul style="list-style-type: none"> • The government policies were biased towards resource-rich large firms and state-owned firms. 	<ul style="list-style-type: none"> • Limited interaction between universities and industry. • Low priority afforded to science, innovation and technology. • Lack of visionary leaders and effective advocacy for science and technology. • Weak links between universities, government and industry. • Limited incentive for basic science research. 	<ul style="list-style-type: none"> • Inadequate expertise to oversee full implementation of STI policy. • Misallocation of the scarce resources to develop capacity in research. • Inadequate attempts to help local firms in catching-up process.

Data sources: synthesised from: Amankwah-Amoah & Sarpong, 2015; MEST, 2009, 2010, 2011; Egu, 2009; CSIR, 2015; Peil, 1996; Lall & Pietrobelli, 2005.

Appendix 1: Public universities, tertiary institutions and research institutes

Institutions	Science and Industrial Research Institutes
University of Ghana, Legon; Kwame Nkrumah University of Science Technology; University of Cape Coast; University of Education Winneba; Ghana Institute of Management and Public administration; University for Development Studies; University of Mines at Tarkwa; University of Mines and Technology, University of Health and Allied Sciences and University of Energy and Natural Resources; Other private universities	Animal Research Institute; Building and Road Research Institute; Food Research Institute; Forestry Research Institute of Ghana; Institute for Scientific & Technological Information; Institute of Industrial Research. Oil Palm Research Institute; Plant Genetic Resources Research Institute; Science & Tech. Policy Research Institute; Soil Research Institute; Water Research Institute; Savanna Agricultural Research Institute;
Polytechnics of Ghana: Accra Polytechnic; Kumasi Polytechnic; Takoradi Polytechnic; Cape Coast Polytechnic; Ho Polytechnic; Tamale Polytechnic; Sunyani Polytechnic; Koforidua Polytechnic; Wa Polytechnic; Bolgatanga Polytechnic.	Crops Research Institute.

Data sources: field notes and government sources.